

THE DISPERSAL OF PLANTS BY FRUIT-EATING BATS.

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Many data are at our disposal about the dispersal of plants by birds, both endozoically and exozoically. Very little, however, is known about the part played in plant dispersal by fruit-eating bats. They are probably as important as the birds, but exact observations are mostly lacking. In H. N. RIDLEY'S well-known handbook on the "Dispersal of Plants throughout the World" three pages are filled with what is known of plant dispersal by bats. These data are based partly on his own observations made during his long and fruitful stay in the tropics, and partly they have been taken from literature. In the same work upwards of 130 pages are given to seed dispersal by birds.

Fruit-eating bats occur in the tropics of the old and of the new world, but they are most numerous in the tropical territories of Asia and Australia. Little is known about their way of living, though they can be observed everywhere. In the twilight these bats come forth from their sleeping places, just like the insect-eating species, and look for their food during the night, to turn back again to their sleeping places at day-break. A few species, *viz.* of the genus *Pteropus*, the Fox-bats, hang down from the branches of large trees, in great numbers together, during the daytime. Others hide themselves, resting in holes, or under folded leaves of palm-trees, or in dark parts of the forests, as I observed several times in Krakatau. In the lake-plains of northern New Guinea I saw large troops, consisting of thousands of individuals, flying low in great circles above the vast *Saccharum*-marshes, during the hottest hours of the day. The animals circled in a quiet, regular flight above the grass covering, and it seemed as if they were asleep. When they were startled by a gun-shot, they flew restlessly in all directions, finally to unite again into the rotary flight. Above these marshes this phenomenon seems to be observed regularly; in 1926 I myself saw it four times, and also during former expeditions it seems to have been perceived, for this place, which is a large island in the river Mamberano, has received the name of Kalong Island, *i.e.* island of flying foxes.

SODY¹ mentioned a few particulars about the modes of life of fruit-eating bats in captivity. These animals seem rarely to be kept in captivity, but SODY succeeded in keeping a female of

1. SODY. Iets over vruchtenetende vleermuizen in gevangenschap. *De Tropische Natuur*. Vol. XVII. 1928, p. 179.

Cynopterus sphinx tithæcheilus, and her young alive for a considerable time. According to him both specimens were hostile to approach. At Bandoeng, I myself kept a specimen of *Pteropus* species in my aviary for a long time; it was very affectionate, crept up my coat, and nestled its head against my neck. According to SODY they seek food late in the evening, take it along to the higher parts of the cage, and eat it while hanging down. Sometimes they hang down by one leg only, using the other to hold the fruit in front of them. In the field he observed that this species broke off the fruits of *Piper aduncum*. Unfortunately nothing is said about the food eaten by the animals in captivity, only that they got soft fruits. Nor are any data given about the digestion of fruits, and the excretion of seeds.

The fruit eating bats mainly live on fruits, but other parts of plants are eaten also. The fruits eaten by these animals are either soft or hard. Soft fruits which are taken may be berries, soft drupes, figs, and gourds. But they eat also fruits with a hard, or rather hard, fruit-shell. These are mainly the larger drupes. These are torn off with the beak, and brought back to the resting places, to which the animals return again and again. They usually choose a spot near the tree from which they gather the fruits, using a branch, roof-gutter, or prominent parts under the roofs or galleries of houses, to hang from. The soft or hard wall is partly or completely gnawed off from the kernel, and the latter is simply dropped. Often they seem to take the fruits along over greater stretches on returning at dawn to their sleeping places, for below them fruit-kernels and seedlings are often found. At Buitenzorg, near my laboratory, there stood a few old specimens of *Corypha Uta*, in which roosted a colony of *Cynopterus sphinx tithæcheilus*. The animals slept in the old, more or less folded and drooping leaves. Under these trees the grass was partly killed by the excreta, but a number of plants developed from the fruits taken home by the bats, and eaten there. They sometimes drop the fruits undamaged during the flight. During the time the large *Canarium commune* bore fruits in the Botanic Gardens, at Buitenzorg, we could often hear the heavy fruits banging down on a zinc pent-house.

These animals probably cannot cover great distances with these heavy fruits. Observations, however, are lacking, and it would indeed be very difficult to make any. But yet many fruits and plants which I found under the above-mentioned sleeping places at Buitenzorg, must have been carried for a distance of hundreds of metres, because in the immediate surroundings of the *Corypha* there were no fruit-bearing trees from which the bats could have taken their food. As the animals

are very voracious, and often eat only a part of the fruit-flesh, these large colonies must destroy enormous quantities of fruits. For the dispersal of fruits over moderate distances they must undoubtedly be of the greatest importance.

VAN DER PIJL¹ tells in an article of recent date that the fruit-flesh is not eaten straight away, but chewed, sucked, and ejected. These animals have a very narrow gullet, measuring in case of *Cynopterus* 2 to 2½ mm. And almost without exception, the intestinal canals of these animals are filled with a colourless jelly. The larger species of *Pteropus* too are said not to contain any seeds in the intestinal canals. MC. CANN² also found only a mucous fluid in the intestines of *Pteropus giganteus*, although the animals had eaten fruits of various species of *Ficus* only a short time before. VAN DER PIJL, however, mentions that seeds of *Ficus fistulosa* have been found in the newly evacuated excrement of a *Cynopterus sphinx*, and that the intestines of *Cynopterus brachyotis*, which had eaten the catkins of *Piper aduncum*, contained seeds of this plant.

According to VAN DER PIJL, fruits eaten by bats have certain characteristics, viz. inconspicuous colour, a smell which is neither fresh nor agreeable, large size, large kernels, hard flesh, while the part of the plants from which the fruits are taken is near open spaces. Such fruits are actually found in the food of bats, but many others, besides which are juicy, fragrant, small, and soft. At any rate, these animals are important because they eat many fruits which are despised by most fruit-eating birds.

Most remarkable is, according to VAN DER PIJL, the cauliflory of many fruits eaten by bats. He observed the following fruits eaten by bats: *Achras Zapota*, *Anona muricata*, *Averrhoa Carambola*, *Bouea macrophylla*, *Canarium spec. div.*, *Carica Papaja*, *Ceiba pentandra*, *Cynometra cauliflora*, *Elæocarpus Ganitrus*, *Eugenia javanica*, *malaccensis*, and *polyantha*, *Ficus fistulosa*, and *glomerata*, *Garcinia Mangostana*, *Lansium domesticum*, *Mangifera cæsia*, *fætida*, and *indica*, *Musa paradisiaca*, *Melia Azedarach*, *Nephelium lappaceum*, *Persea americana*, *Psidium Guajava*, *Phyllanthus acidus*, and *Embllica*, *Sechium edule*, *Spondias*, and *Zalacca edulis*.

In case of species of large fruits with large kernels only the wall is eaten away, but the soft fruits with small seeds are eaten either whole, or part of them. A great number of seeds are

1. L. VAN DER PIJL. Zaadverspreiding door vleermuizen. De Tropische Natuur, Vol. XXIV. 1935, p. 131.

2. MC. CANN. Notes on the flying fox (*Pteropus giganteus*). Journ. Bomb. Nat. Hist. Soc. Vol. XXXVII. (Quoted from VAN DER PIJL.).

eaten together with the flesh in which they are imbedded. In the case of figs they are really small fruits covering the inner wall of the receptaculum, but I will call them "seeds". The juicy fruits are digested in the intestinal canal, and the seeds come forth undamaged together with the excreta. These excreta are dropped, not only in the resting places, but also during the flight, so that the seeds can come down in all kinds of places. They are hardly ever found on the ground, because here they are hidden between plants, but often on leaves, stones, and walls. The excreta are of a very fluid consistency, often jelly-like. I often saw the seeds of *Piper aduncum* on leaves in the surroundings of Buitenzorg. I saw leaves with excreta containing seeds of *Ficus* in Krakatau, where there is a very great number of two species of fruit-eating bats, *Cynopterus Horsfieldii* and *C. sphinx tithæcheilus*; in the higher parts of the same island I found excreta principally containing seeds of *Cyrtandra sulcata*. The excreta also often come down on buildings, and young plants of *Ficus Benjamina* and of *F. retusa* can often be seen growing in the gutters. When the seeds come down on old, badly kept buildings, or on old temples, then the roots of these large species of *Ficus* can slowly break the stones asunder, and do much damage.

The animals need not rest while eating these juicy fruits, and thus the seeds can be carried over greater distances than in the case of big fruits with a hard kernel. It is not known how long a time the seeds need to pass through the intestinal canal of bats in the digestive process. It would be important to study this.

In the islands north of Batavia there are large colonies of *Pteropus*, and the animals fly over to the shore of Java, late in the afternoon, or early in the evening, in order to look for food. When at sea one can often see large groups of these animals crossing wide sea-arms. Undoubtedly these animals have played a part in the dispersal of seeds to the islands of the Krakatau-group. It is not known when these animals have arrived there. JACOBSON¹ who examined the fauna of these islands in 1908 fails to mention them, but in 1919 they were quite common, and DAMMERMAN² mentions them in 1922.

The first to write about plant dispersal by bats was RUMPHIUS, in his well-known *Herbarium Amboinense*. He mentions *Nauclea elegans*, *Artocarpus integra* and *communis*, besides *Anona mucosa*, and two species of *Mangifera*, the seeds of which are spread by bats. In addition many data can be found in the above mentioned work of RIDLEY.

1. E. R. JACOBSON. De nieuwe fauna van Krakatau. Jaarverslag van den Topographischen Dienst in Nederlandsch Indië over 1908. Batavia, 1909, p. 192.
2. K. W. DAMMERMAN. The fauna of Krakatau, Verlaten Island and Sebesy. Treubia, Vol. III. 1922, p. 65.

An examination of the contents of the intestinal canals of these animals might produce important results. Up till now only a few facts are known. One might also collect the fruits and seeds from the excreta. Another way of carrying out the investigations with a greater chance of success, is the observation of plants which regularly come up under the sleeping and resting places of these animals. During the many years which I stayed in Java, I noted down, here and there, which species of plants occurred in such places. In a few cases it was not possible to recognize the species of plant from the young, non-flowering materials. It appeared from these observations that numerous species of plants are spread by these bats; the appended list, undoubtedly, does not contain all the species which are actually eaten and dispersed. The list, moreover, shows that it is mainly species of trees from which the bats take their food. Yet one sees among them also smaller plants, such as *Clibadium surinamense*, *Passiflora foetida*, a *Zingiberacea*, and an Aroid.

Some plants owe their quick dispersal mainly to these animals. *Piper aduncum* is a small tree which has been imported to the Botanic Gardens at Buitenzorg from tropical America. The trees, which are 2 to 6 m high, often bear large quantities of fruit-catkins, which are principally eaten by the smaller species of fruit-eating bats. Owing to this the plant has spread very quickly in the surroundings of Buitenzorg, and farther in West Java. Large quantities occur in grass jungles, in valleys, and in kampong wildernesses, where often it may crowd out the original flora.

Below is given a list of the species of plants which I have found. Most observations have been made in Buitenzorg, but also in Batavia, Bandoeng, Samarang, Cheribon, and other smaller places, wherever I had the opportunity. As I was not able to state the species of bats, I give the list without indicating them. Among the plants found in Buitenzorg there are several species of trees which are cultivated in the Botanic Gardens.

Young plants found under the resting and sleeping places of fruit-eating bats:—

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|---------|------------------------------------|-------------------------------------|
| MORACEÆ | | URTICACEÆ. |
| 1. | <i>Artocarpus communis</i> FORST. | 16. <i>Pipturus incanus</i> WEDD. |
| 2. | „ <i>elastica</i> REINW.
et BL. | PIPERACEÆ. |
| 3. | „ <i>integra</i> MERR. | 17. <i>Piper aduncum</i> L. |
| 4. | <i>Ficus ampelas</i> BURM. | 18. „ <i>retrofractum</i> VAHL. |
| 5. | „ <i>Benamina</i> L. | EUPHORBACEÆ. |
| 6. | „ <i>callosa</i> WILLD. | 19. <i>Antidesma Bunius</i> SPR. |
| 7. | „ <i>elastica</i> ROXB. | 20. <i>Baccaurea racemosa</i> M. A. |
| 8. | „ <i>fistulosa</i> REINW. | ANONACEÆ. |
| 9. | „ <i>fulva</i> REINW. | 21. <i>Anona muricata</i> L. |
| 10. | „ <i>hispida</i> L. | 22. <i>Species ignota</i> . |
| 11. | „ <i>infectoria</i> ROXB. | LAURACEÆ. |
| 12. | „ <i>pilosa</i> REINW. | 23. <i>Litsea polyantha</i> JUSS. |
| 13. | „ <i>retusa</i> L. | 24. „ <i>species</i> . |
| 14. | „ <i>septica</i> BURM. | |
| 15. | „ <i>variegata</i> BL. | |

FLACOURTIACEÆ.

25. *Flacourtia Rukam* Z. et M.

PASSIFLORACEÆ.

26. *Passiflora foetida* L.

CARICACEÆ.

27. *Carica Papaja* L.

GUTTIFERÆ.

28. *Calophyllum Inophyllum* L.

29. „ „ species.

30. *Ochrocarpus congregatus* BOERL.

LEGUMINOSÆ.

31. *Cynometra cauliflora* L.

32. *Maniltoa gemmipara* SCHEFF.

MYRTACEÆ.

33. *Eugenia aquea* BURM. f.

34. „ „ *malaccensis* LAM.

35. „ „ *polyantha* WIGHT.

36. „ „ species.

COMBRETACEÆ.

37. *Terminalia Catappa* L.

38. „ „ species.

MELASTOMATACEÆ.

39. *Melastoma malabathricum* L.

MALVACEÆ.

40. *Durio Zibethinus* L.

ELÆOCARPACEÆ.

41. *Elæocarpus* species.

RUTACEÆ.

42. *Evodia* species.

BURSERACEÆ.

43. *Canarium commune* L.

44. „ „ species.

MELIACEÆ.

45. *Aglaja* species.

46. *Dysoxylum* species.

47. *Lansium domesticum* CORR.

48. *Melia Azedarach* L.

49. *Sandoricum Kœtjape* MERR.

ANACARDIACEÆ.

50. *Gluta Renghas* L.

51. *Mangifera indica* L.

52. „ „ species.

53. *Spondias dulcis* FORST.

SAPINDACEÆ.

54. *Nephelium lappaceum* L.

55. *Sapindus Rarak* DC.

EBENACEÆ.

56. *Diospyros* species.

57. „ „ species.

LOGANIACEÆ.

58. *Fagraea* species.

RUBIACEÆ.

59. *Morinda citrifolia* L.

CUCURBITACEÆ.

60. *Trichosanthes* species.

COMPOSITÆ.

61. *Clibadium surinamense* L.

var. *asperum* BAKER.

ZINGIBERACEÆ.

62. *Amomum* species.

MUSACEÆ.

63. *Musa* species.

PALMÆ.

64. *Actinophlœas angustifolius* BECC.

65. *Arenga pinnata* MERR.

66. *Bactris speciosa* KARST.

67. *Caryota Rumphiana* MART.

68. *Corypha Utan* LAMK.

69. *Livistona rotundifolia* MART.

70. *Oncosperma filamentosa* BL.

ARACEÆ.

71. *Colocasia* species.